PATENT SPECIFICATION

Inventors: JOHN FRANCES BETTERIDGE and MARVIN WILLIAM KEARY

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COMPLETE SPECIFICATION

Improvements in or relating to Combustion Chambers for Gas Turbines

We, THE BIRMINGHAM SMALL ARMS COMPANY LIMITED, of Armoury Road, Small Heath, Birmingham 11, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to combustion chambers for gas turbines.

In known combustion chambers of gas turbines, particularly those used for aircraft, primary air enters the flame tube of the combustion chamber at low velocity around and coaxially with the fuel, the air being caused to rotate in a direction reverse to that in which the fuel is caused to rotate so as to mix with the fuel within a combustion space which is defined at the inlet end by a conical end plate which diverges from the fuel and air inlets. Apertures in the end plate allow additional primary air to enter. From the wide end of the conical end plate, the flame tube is continued by successive walls which are generally cylindrical and either have apertures therein for the supply of secondary and tertiary air from an annular space between the flame tube and an outer chamber, or have apertures in annular connections between wall sections, for the same purpose. Primary air is drawn from the said space through an opening, surrounding the fuel pipe, in the narrow end of a conical member located in advance of the conical end plate of the flame tube. Apart from the relatively slight effect of the entry of secondary air, the combustion products proceed as a long flame in a generally axial direction to the outlet of the flame tube.

In such known combustion chambers, incomplete mixing of fuel with primary and secondary air can occur and furthermore unmixed fuel or fuel mixed with air can escape being burnt in the primary zone.

It is an object of the present invention to provide a flame tube for gas turbine combustion chambers in which there is provision for deflection of unburnt fuel or fuel/air mixture into the central part of the flame tube to be burnt there. Further objects of the invention are to give a stable flame over a wide range of fuel/air ratios, a short flame length, a high heat release, and to minimise the formation of carbon deposites.

According to the invention, a flame tube for a gas turbine combustion chamber has primary and secondary combustion zones the primary zone diverging from the fuel inlet at one end and sharply converging at the other end to form a throat from which diverges the secondary zone, apertures being formed in the divergent wall of the primary combustion zone for admission of primary air and in the divergent wall of the secondary combustion zone for admission of secondary air.

The apertures for the admission of primary air, or some of them, may be provided with means for causing the admitted air to swirl peripherally.

Primary air admitted through the said apertures meets or cuts across the path of droplets of fuel projected from the burner and causes the droplets to be broken up into a fine mist and readily mix with the primary air. A suitably disposed igniter plug serves to ignite the mixture which burns in the centre of the primary zone. Any unburnt fuel or fuel/air mixture remote from the axis impinges against the convergent wall forming the throat and is vaporised and deflected inwardly towards the burning mixture at the centre and is there burnt.

Air admitted through the apertures in the wall of the primary zone, or some of them, also serves, by its swirling, to scrub the inside surface of the flame tube and thereby minimises the formation of deposited carbon. Furthermore, the throat serves, on escape of the burning mixture therethrough, to increase the

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velocity of the burning mixture, secondary air being added to it as it passes through the secondary zone.

There may be air admission apertures in the throat itself, but provision of such apertures can give rise to burning of the throat material round the orifices of the apertures.

The secondary zone may be extended by a continuation portion from the divergent wall of the secondary zone. Such continuation portion may be cylindrical or be divergent but to a lesser degree than the divergent wall, or be convergent, and may be provided with apertures for the admission of tertiary air. In a further alternative, the secondary zone may diverge comparatively gradually from the throat.

The primary zone may consist of two opposed conical portions connected by a smooth curve at their wider ends, one of the portions merging smoothly into the throat.

Alternatively, the primary zone may be part spherical and merge smoothly into the throat, or be pear-shaped, that is, have a conical portion merging smoothly into a part-spherical portion which merges smoothly into the throat.

The flame tube may be used with "straight through," "reverse flow" or "elbow" types of air supply.

In order that the invention may be fully understood and more readily carried into practice, we have caused to be appended hereunto drawings illustrating various constructional examples thereof, wherein—

Figure 1 is a side view in vertical medial section of a flame tube for a gas turbine combustion chamber,

Figure 2 is an end view of the flame tube shown in Figure 1,

Figure 3 is a side view in medial section, and illustrates another construction,

Figure 4 is a similar view to Figure 3, illustrating a further construction,

Figure 5 is a similar view to Figure 3, and illustrates still another construction,

Figure 6 is a diagrammatic side view in medial section, and illustrates a still further construction, and

Figure 7 is a similar view to Figure 6, illustrating still another construction.

Referring to the drawings, in the construction shown in Figures 1 and 2 thereof, a flame tube 1 for a gas turbine combustion chamber has a hollow cylindrical portion 2 adapted to surround and contain a fuel burner, shown in dot-and-dash lines and designated 3. The portion 2 is connected to a portion 4 which diverges steeply in conical manner and is connected to a convergent portion 5 of similar but reverse conicity by a smoothly rounded curved portion 6. The portion 5 is connected to a divergent portion 7 of similar conicity to that of the portion 4 by a smoothly rounded portion 8, the portons 5, 7 and 8 together forming a throat 9 which at its narrowest point is of greater diameter than that of the hollow cylindrical portion 2. The divergent portion 7 is succeeded by a cylindrical portion 10 which is of greater length than any of the other flame tube portions. The portion 10 terminates in a mouth 11 of the flame tube 1.

The portions 4, 5 and 6 constitute the primary combustion zone of the flame tube and fuel from the burner 3 burns and is supplied with primary air through a series of apertures 12 spaced peripherally around the portion 4. Further primary air may be supplied through apertures 13, supplied with air through a swirling ring 14 mounted on the exterior of the portion 4 and serving to impart a swirling motion to air admitted through the apertures 13, such air tending to sweep the interior surface of the flame tube and discourage the formation of carbon deposits thereon. Fuel from the burner 3 is discharged therefrom in the form of a divergent conical spray, and primary air admitted through the apertures 12 and 13 cuts across the paths of the fuel droplets and breaks up the droplets into a fine mist. Any fuel or fuel-air mixture which is not immediately burned strikes the walls of the convergent portion 5 and is deflected thereby inwardly towards the axis of the flame tube where it is burned. Any droplets of fuel which have escaped being broken up or vapourised by the primary air entering the flame tube are caused to be broken up or vapourised on impinging against the wall of the portion 5.

The provision of the throat 9 serves to increase the velocity of the burning mixture of fuel and air and acts in the manner of a Venturi tube, causing a region of low pressure in the portion 7 of the tube immediately succeeding the throat 9. This portion is provided with a row of peripheral apertures 15 through which secondary air is admitted and drawn in by the said region of low pressure. Tertiary air is admitted to replace that which is displaced in the portion 10 by the passage of the burning gases, through a series of peripheral apertures 16 in the portion 10.

The flame tube 1 is secured in position in an air supply chamber, shown in dot-and-dash lines and indicated by the reference numeral 17, air being admitted to this chamber so that it flows in a direction parallel to that of the flame ("straight through"), as indicated by the arrow *A* in Figure 1, or through an aperture 18 adjacent the primary air apertures 12 and 13 ("elbow") or through an aperture 19 near the mouth 11 of the flame tube to flow in the direction indicated by the arrow *B* in Figure 1 ("reverse flow"). One advantage of the "reverse flow" method of air supply is that the air is pre-heated as it flows in contact with the hot flame tube before being admitted thereto, but this method suffers from the disadvantage, where the gas turbine is employed in aircraft, that it is not always possible to cause sufficient air to flow in a direction reverse to the direction of flight without employing a compressor of unduly large capacity, the extra power needed for which is not always completely off-set by the improved efficiency of combustion produced by the admission of pre-heated air.

In another construction, illustrated in Figure 3, a flame tube 20 is similar to that described with reference to Figures 1 and 2, except that, instead of having a comparatively sharply-divergent portion succeeding the throat, a less sharply-divergent portion 21 is provided and extends directly from the throat 22 in divergent manner to the mouth 23 of the flame tube. This portion forms both the secondary and tertiary zones, and has peripheral apertures 24 adjacent the throat 22 for the supply of secondary air and a series of peripheral apertures 25 for the supply of tertiary air. The primary zone 26 is similar to that in the hereinbefore described construction. A swirling ring (not shown) to co-operate with peripheral additional primary air apertures 27, may be provided.

In a further construction, illustrated in Figure 4, a flame tube 28 is similar to that described with reference to Figures 1 and 2, except that, instead of a long cylindrical portion being connected to a portion diverging sharply from the throat, a less sharply-divergent portion 29 succeeds a fairly short sharply-divergent portion 30 extending from the throat 31. Apertures 32 for the supply of secondary air are provided in the portion 30, and apertures 33 for the supply of tertiary air are provided in the portion 29. The primary zone 34 is similar to that of the first-described construction, and a swirling ring (not shown) may be provided to co-operate with peripheral additional primary air apertures 35.

In still another construction, illustrated in Figure 5, a flame tube 36 is similar to that described with reference to Figures 1 and 2, except that a sharply-divergent portion 37 succeeding the throat 38 is extended for rather more than that of the first-described construction and is succeeded by a slightly-convergent portion 39 terminating in a mouth 40. A swirling ring (not shown) may be provided for the primary zone 41, which is similar to that of the first-described construction, to co-operate with peripheral additional primary air apertures 42.

In the constructions shown diagrammatically in Figures 6 and 7, different shapes of primary combustion zone are employed. The primary combustion zone 43 shown in Figures 6 is part-spherical and has a throat 44 succeeded by either a divergent portion 45 and succeeding cylindrical portion 46, both shown in full lines, or a portion 47 slightly diverging direct from the throat 44, or a convergent portion 48 succeeding the portion 45, or a divergent portion 49 succeeding the portion 45, the portions 47, 48 and 49 being shown in dot-and-dash lines. The primary combustion zone 50 shown in Figure 7 is pear-shaped, that is, has a divergent conical portion 51 flowing smoothly into a part-spherical portion 52 which terminates in a throat 53 which can be succeeded by any of the alternative portions referred to in connection with the construction shown in Figure 6. In either of these alternative constructions, swirling rings (not shown) can be provided for co-operation with peripheral additional primary air apertures as hereinbefore described.

The provision of the throat in all the constructions serves to increase the velocity of the burning fuel-air mixture as it escapes therethrough. Furthermore, because of the good mixing of air and fuel in the bulbous primary combustion zone, and because of the mixing which takes place on approach to and passage through the throat, final combustion after the throat takes place at low air-fuel ratios. Flame length is kept short and can be controlled by the diameter of the throat, and a high rate of heat release is obtained. Combustion is extremely rapid, and even with heavier fuel than kerosene, little carbon is deposited.

In all constructions, air apertures may be provided in the throat itself (not shown), but their provision is not preferred because it can give rise to burning of the throat material round the aperture orifices.

WHAT WE CLAIM IS:—

1. A flame tube for a gas turbine combustion chamber, having primary and secondary combustion zones the primary zone diverging from the fuel inlet at one end and sharply converging at the other end to form a throat from which diverges the secondary zone, apertures being formed in the divergent wall of the primary combustion zone for admission of primary air and in the divergent wall of the secondary combustion zone for admission of secondary air.

2. A flame tube according to claim 1, wherein some or all of the apertures for the admission of air to the primary combustion zone are provided with means for causing the admitted air to swirl peripherally.

3. A flame tube according to either of the preceding claims, wherein there are apertures in the said throat for the admission of air for combustion.

4. A flame tube according to claim 1, wherein the secondary combustion zone is extended by a continuation portion from the divergent wall of the secondary zone.

5. A flame tube according to claim 4, wherein the continuation portion is cylindrical, or divergent but to a lesser degree than the said divergent wall, or convergent, and is provided with apertures for admission of tertiary air.

6. A flame tube according to any of claims

1 to 4, wherein the secondary combustion zone diverges comparatively gradually from the said throat.

7. A flame tube according to any of the preceding claims, wherein the primary combustion zone consists of two opposed conical portions connected by a smooth curve at their wider ends, one of the portions merging smoothly into the throat.

8. A flame tube according to any of claims 1 to 6, wherein the primary combustion zone is part-spherical and merges smoothly into the throat.

9. A flame tube according to any of claims 1 to 6, wherein the primary combustion zone is pear-shaped, that is, has a conical portion merging smoothly into a part-spherical portion which merges smoothly into the throat.

10. A flame tube according to any of the preceding claims, employed with either "straight-through," "reverse flow" or "elbow" types of air supply to the air admission apertures.

11. For a gas turbine combustion chamber, a flame tube substantially as hereinbefore described with reference to Figures 1 and 2, Figure 3, Figure 4, Figure 5, Figure 6, or Figure 7 of the accompanying drawings.

NORMAN H. BUCKLEY,
Chartered Patent Agent,
Agent for the Applicants.

PROVISIONAL SPECIFICATION

Improvements in or relating to Combustion Chambers for Gas Turbines

We, THE BIRMINGHAM SMALL ARMS COMPANY LIMITED, a British Company, of Small Heath Works, Birmingham, 11, do hereby declare this invention to be described in the following statement:—

This invention relates to combustion chambers for gas turbines, the object of the invention being to provide a flame tube for such combustion chambers that will give a stable flame over a wide range of air/fuel ratios, a short flame length, and a high heat release; also to minimise the formation of carbon deposits.

In the usual combustion chamber of gas turbines, particularly those used for aircraft, the primary air enters the flame tubes at low velocity round and coaxially with the fuel, therebeing swirling vanes to rotate the air in a direction reverse to that of the swirling fuel and to assist in mixing within a combustion space that is closed at the inlet end by a conical end plate that diverges from the fuel and air inlets. Holes in the end plate provide for the entry of additional primary air. From the wide end of the conical end plate, successive generally-cylindrical walls continue the combustion chamber, with holes in the walls, or in annular connections between the walls, for the admission of secondary and tertiary air from an annular space between the combustion chamber and the wall of an outer chamber. The primary air is drawn from the same supply of air through an opening round the fuel pipe in the narrow end of a conical member located in advance of the conical end plate of the combustion chamber. Apart from the relatively slight effect of secondary air entering by the holes in the continuation walls of the combustion chamber, the combustion products proceed as a long flame in a generally axial direction to the outlet of the combustion chamber.

In contrast with such a combustion chamber, the invention provides that any of the fuel/air mixture that is not completely burnt in the primary zone is deflected into the central part of the chamber; it also provides more effective mixing of secondary air with the combustion products, as well as providing for the addition of any tertiary air that may be required.

Accordingly, a flame tube for a gas turbine combustion chamber according to the invention comprises a primary combustion section that diverges from fuel and air inlets at one end and sharply converges to an axial throat at the other end, and a secondary combustion section diverging from the throat, with admission holes for primary air in the divergent wall of the primary section and provision for the supply of secondary air beyond the throat outlet of the primary section.

The fuel burner is of the type serving to discharge the fuel as a divergent conical spray, and the primary air is preferably admitted by two or more series of holes in and round the wall of the part of the primary section that diverges from the burner. Primary air thus entering cuts across the paths of the droplets in the conical fuel spray and breaks up the droplets into a fine mist. "Lighting-up" is effected by a suitably placed igniter plug and the mixture burns in the centre of the section. Any fuel/air mixture that is not burnt immediately then strikes the convergent wall of the primary section, where the fuel is vaporised and deflected inwardly into the burning mixture.

There may also be the usual swirling plates fitted round the burner to rotate the primary air that is about to meet the fuel spray.

The air admitted through the holes in the wall of the primary section also serves to scrub the inside of this section, and thus minimises the formation of deposits.

The burning mixture increases its velocity as it escapes through the throat, from which point further air is mixed with it in the desired ratio. Thus, secondary air may be admitted by holes in the walls of the divergent secondary section. There may be air-admission holes in the throat itself, but at the risk of burning of the metal round the holes. Again, if this secondary section is short, and of relatively wide angle, secondary air may swirl round its edge into the stream passing through the section, mixing being aided by turbulence resulting from the wide angle of the section. Yet again, the divergent secondary section may be continued by a generally cylindrical section, with holes in its wall for the entry of tertiary air.

The secondary section may, however, be extended in length and diverge at a relatively small angle, with holes in its wall for final combustion air.

Because of the good mixing of air and fuel in the bulbous combustion zone formed by the diverging and converging walls of the primary section, and the mixing that takes place on approach to and passage through the throat, final combustion after the throat takes place at low air/fuel ratios. Flame length is kept short (as may be controlled by the diameter of the throat) and a high rate of heat release is achieved. Combustion of the fuel is extremely rapid, so that even when heavier fuel than kerosene is used there is little likelihood of carbon being deposited.

The bulbous primary section may consist of two opposed cones, connected by a smooth curve at their peripheries, with the second cone merging smoothly into the throat and thence to the divergent secondary section. If the secondary section is elongated, as indicated above, the throat and the secondary section closely resemble a Venturi tube. The primary section may, however, be spherical or approximately so, e.g. pear-shaped.

The flame tube may be used with the "straight-through" combustion chamber as generally used for multi-chamber gas turbines for aircraft turbines. It may also be used with "reverse flow," and "elbow" types of combustion chambers.

HULSE & WAITE,
Chartered Patent Agents,
269, Glossop Road, Sheffield, 10.

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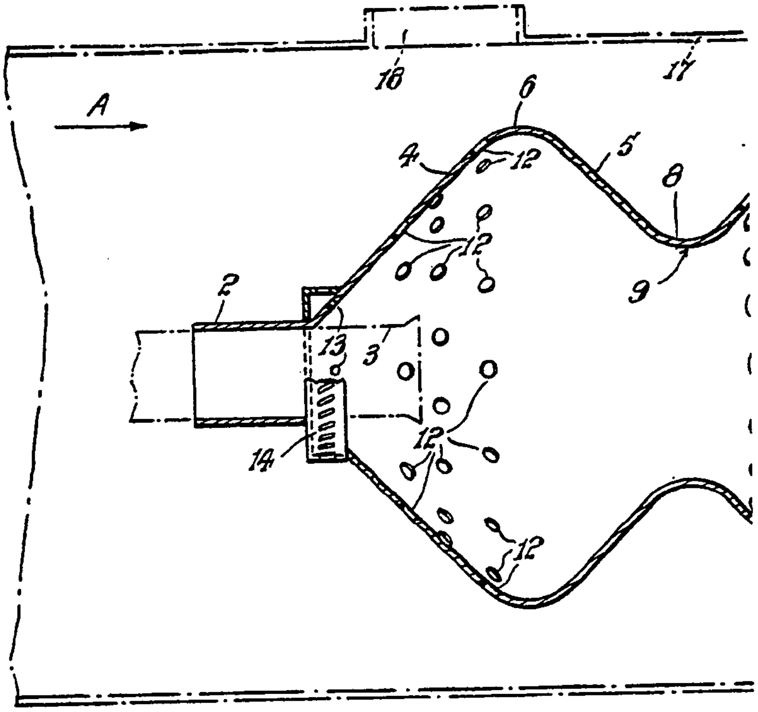

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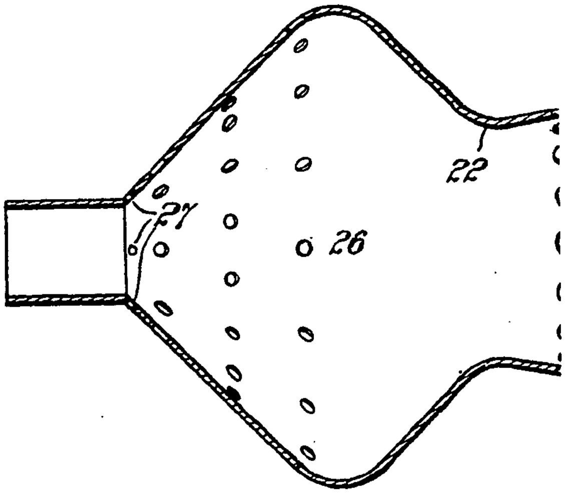

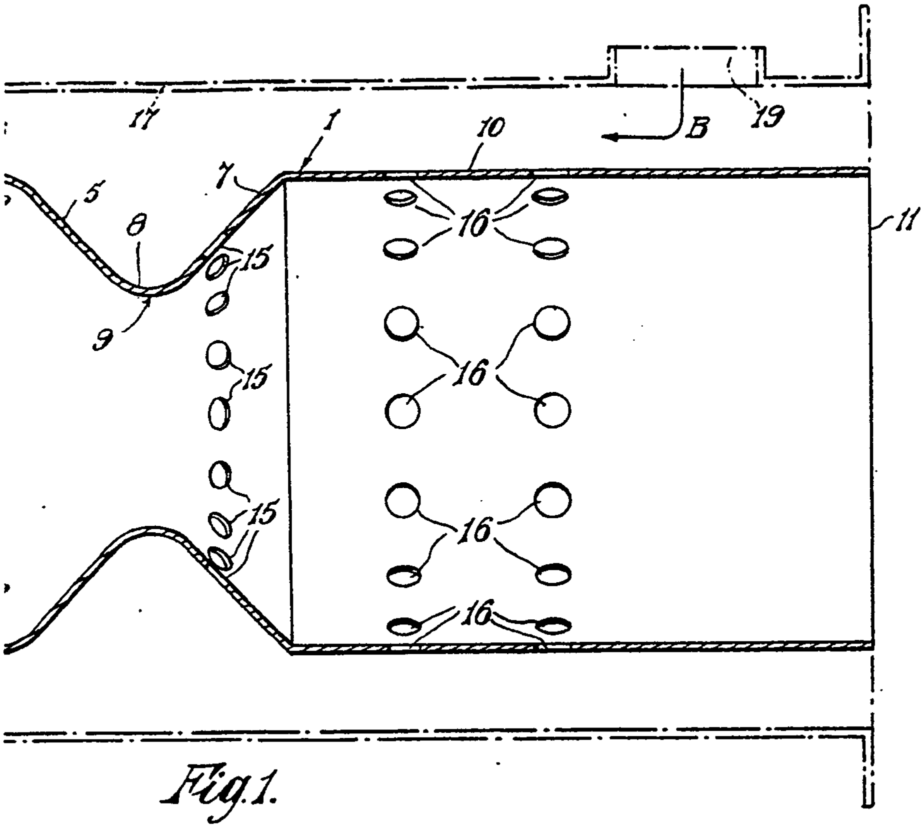
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Fig.1.

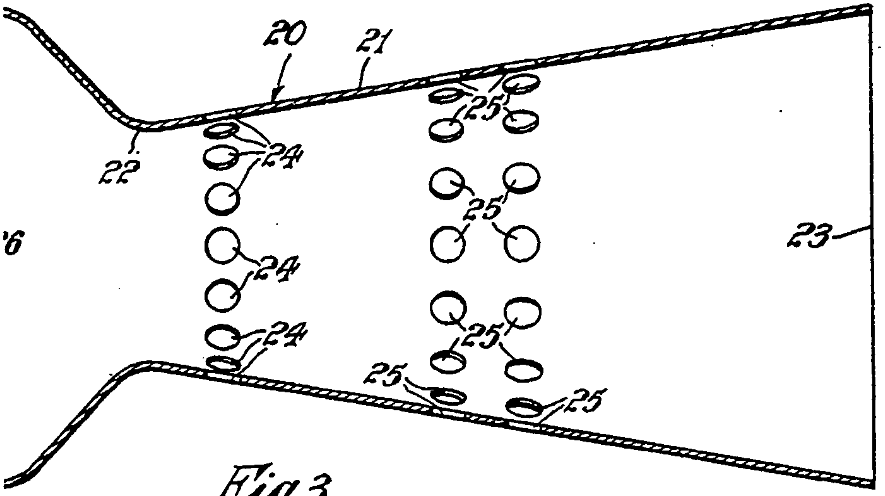
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Fig.3.

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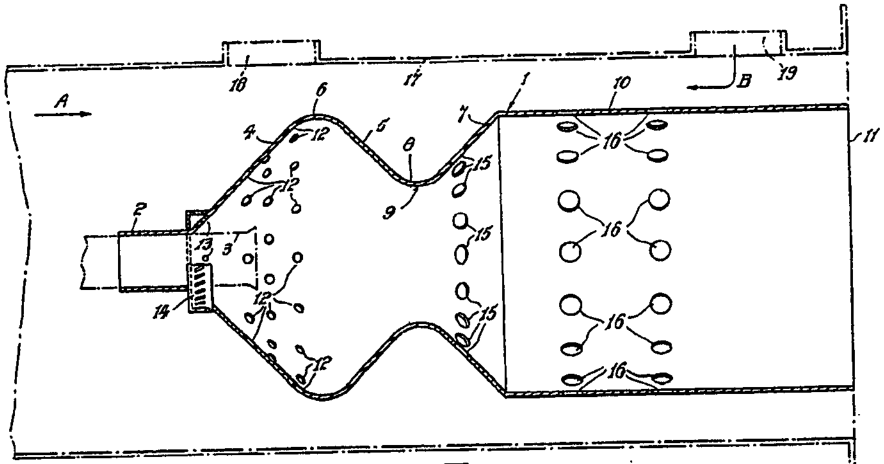

Fig.1.

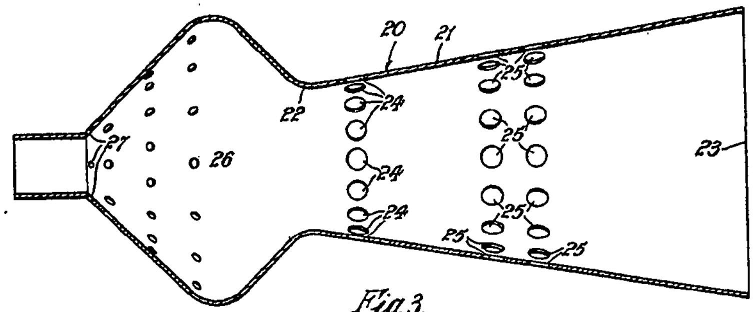

Fig.3.

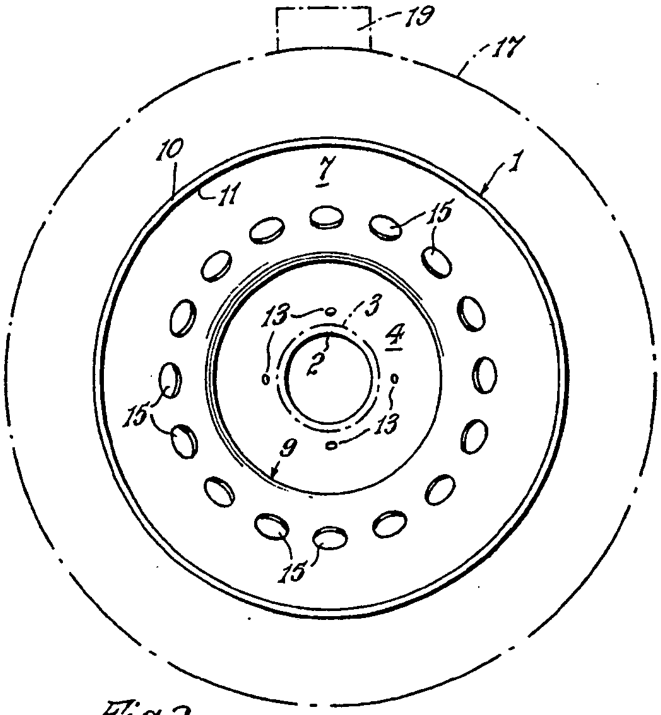

Fig.2.

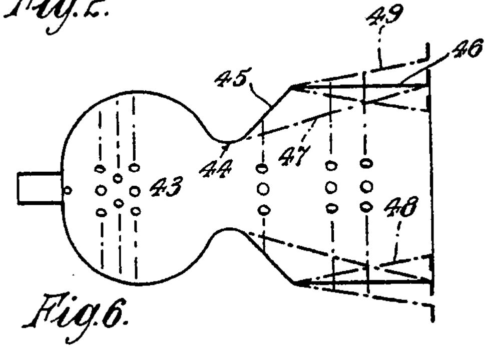

Fig.6.

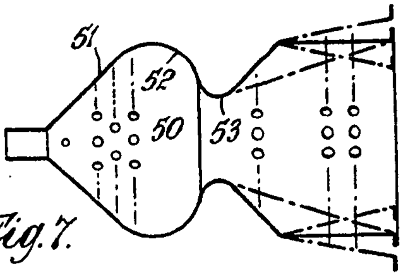

Fig.7.

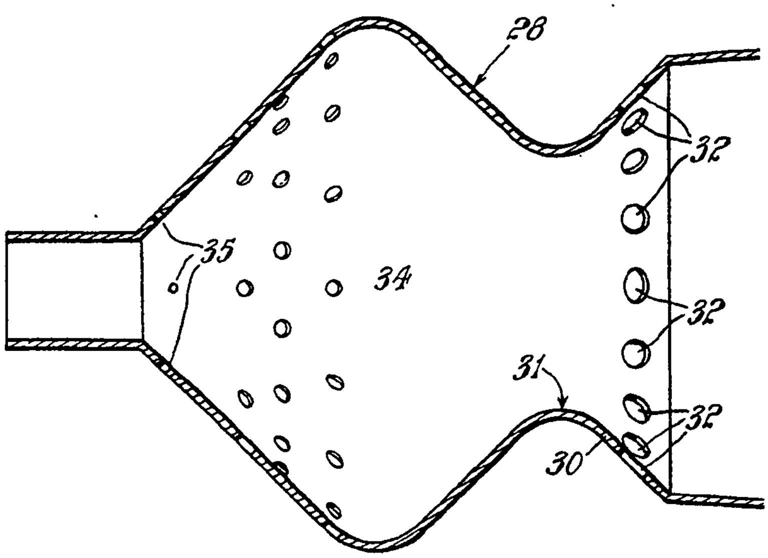

Fig.4.

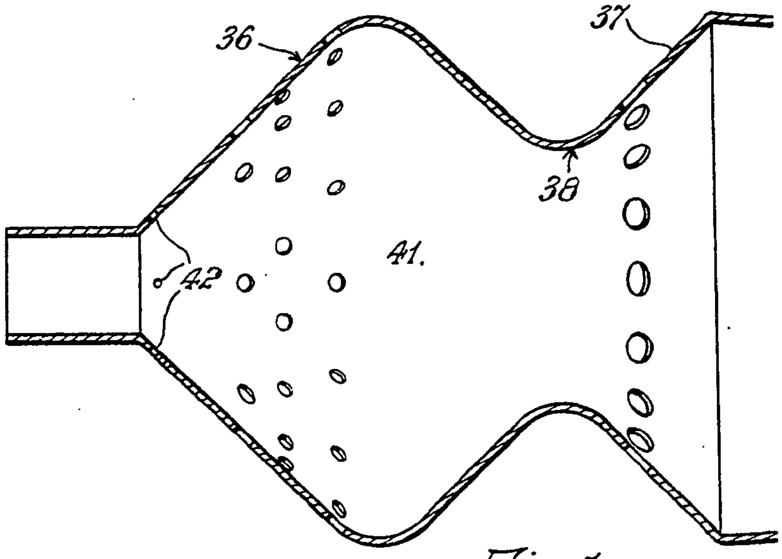

Fig.5.

818,634 **COMPLETE SPECIFICATION**
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SHEET 3

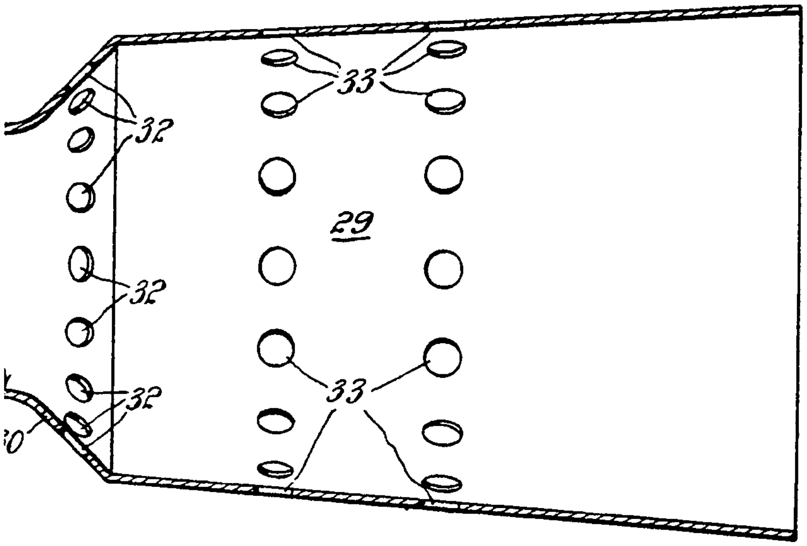
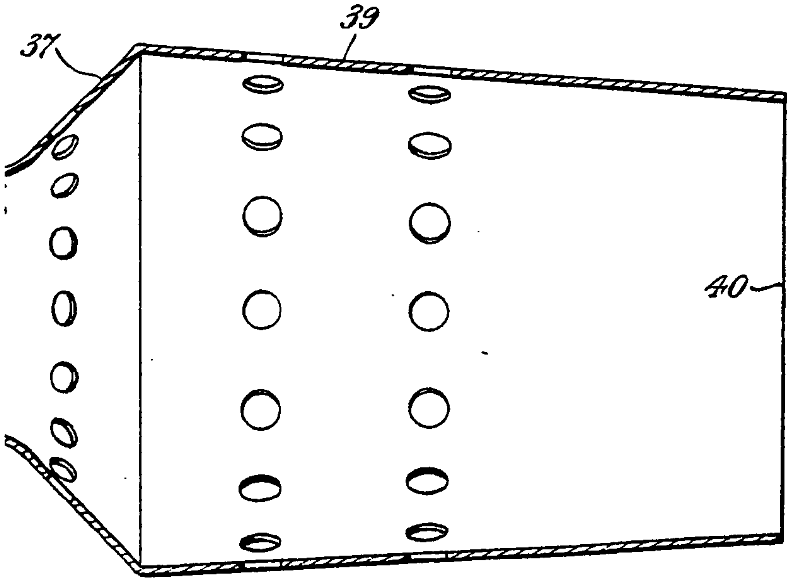


Fig. 4.



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818,634 COMPLETE SPECIFICATION
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SHEET 3

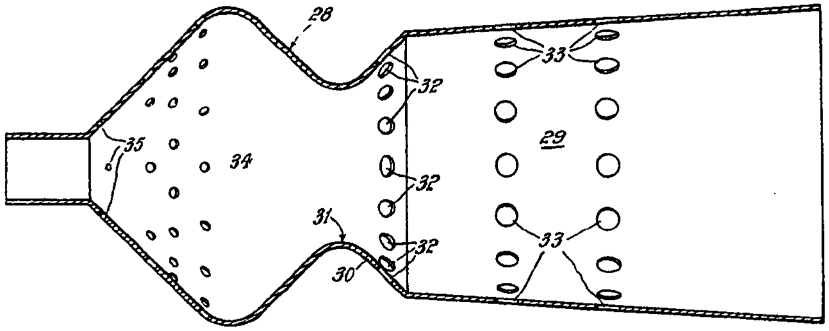

Fig.4.

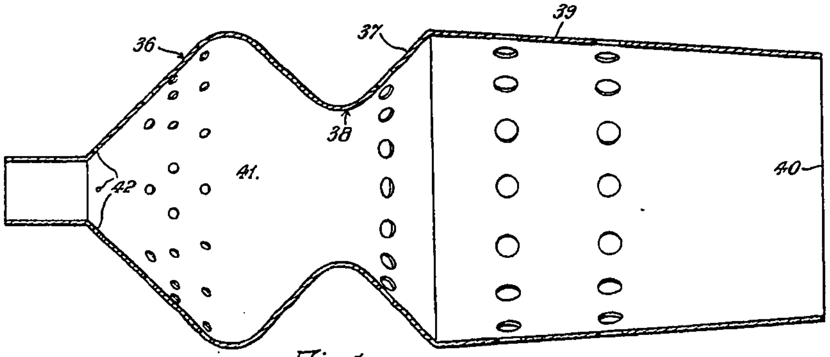

Fig.5.